Development of a test framework for evaluating USB charging ports of pico PV systems and solar home systems

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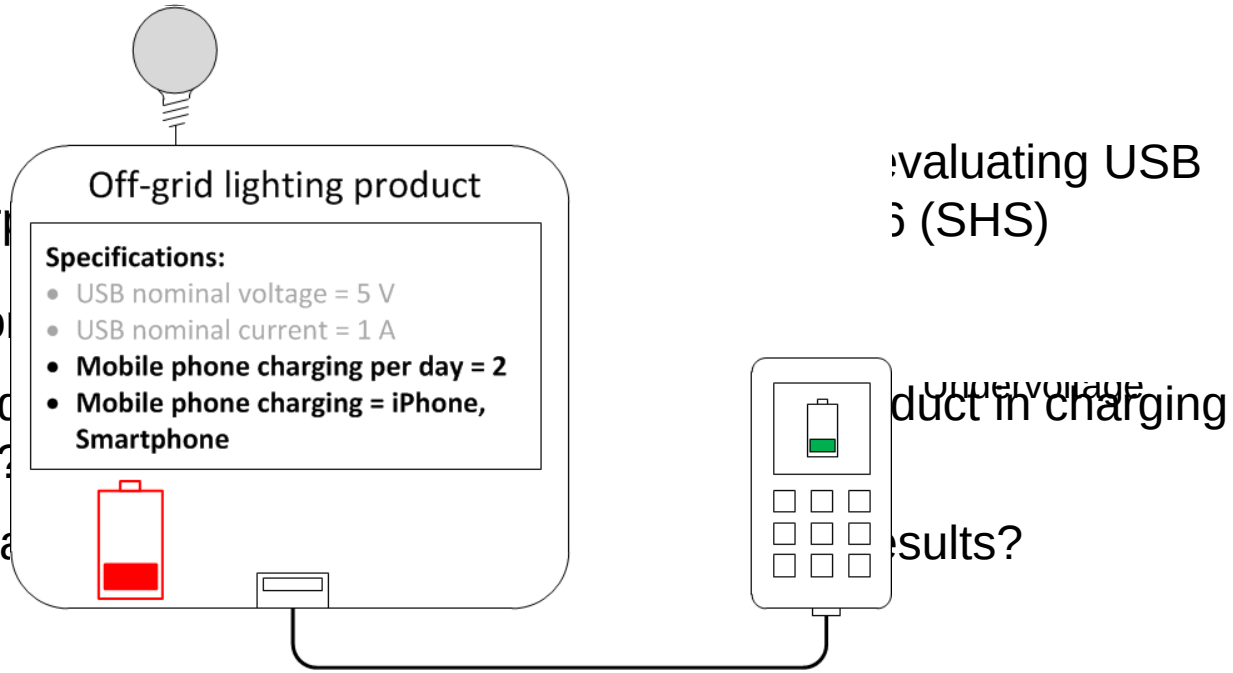
- Conclusion

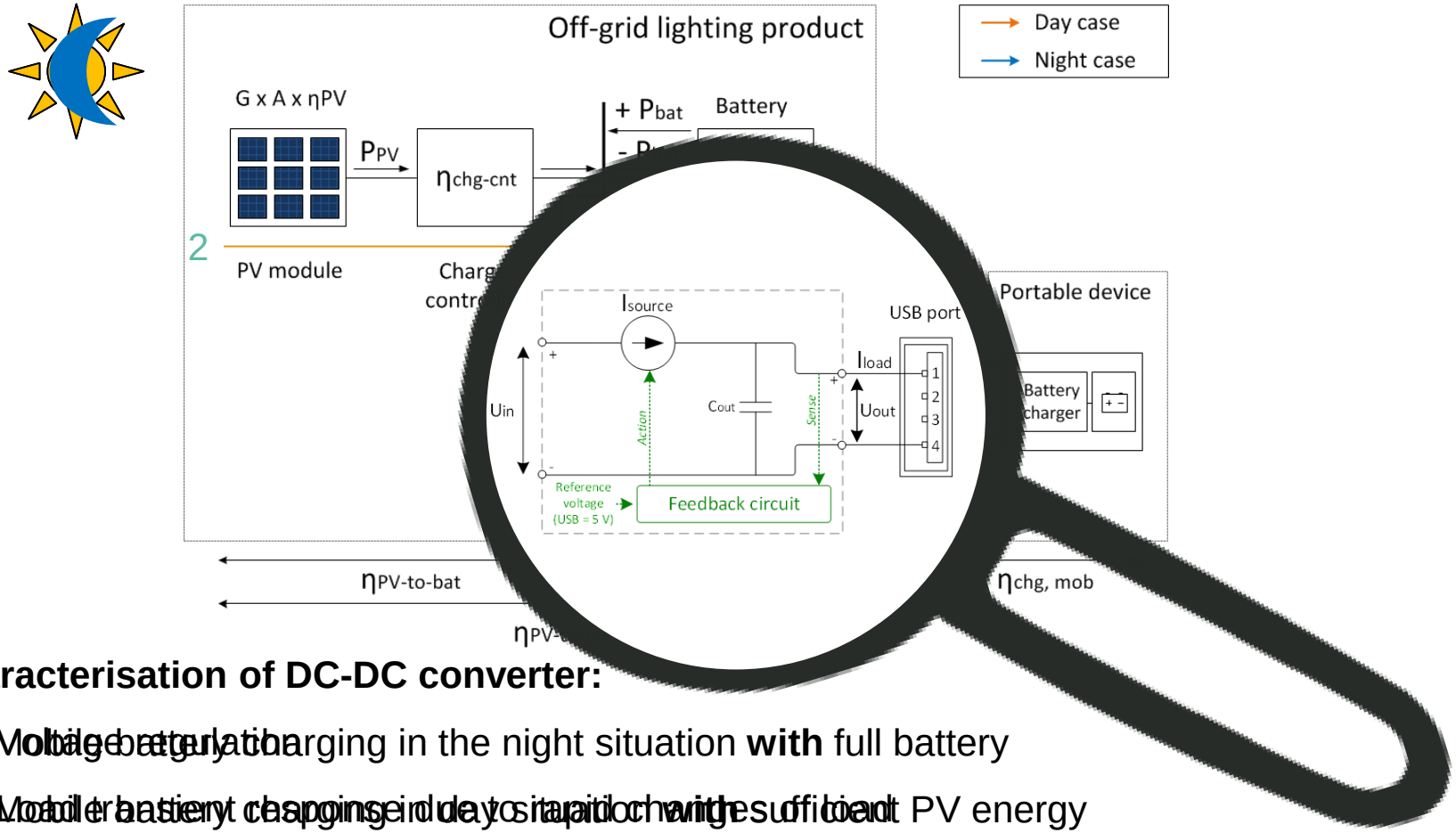
Introduction

- Motivation
  - Increasing market penetration of off-grid lighting products and mobile phones in Africa and Asia → **Quality Assurance**
    - Protect the consumers from malfunctioning USB charging port
    - Ensure the truth in advertising
- Objectives
  - Create a fast, …valuating USB port and incor… (SHS)
- Research questio…
  - What are the … duct in charging mobile phone?
  - How to avoid … esults?



Background information

Power flow in an off-grid lighting product for charging a portable device



Characterisation of DC-DC converter:

- Mobile battery charging in the night situation **with** full battery
- Mobile battery charging in day situation **with** sufficient PV energy
- Mobile battery charging in day situation **without** sufficient PV energy

Source : [1]Simpson, C. ,2007

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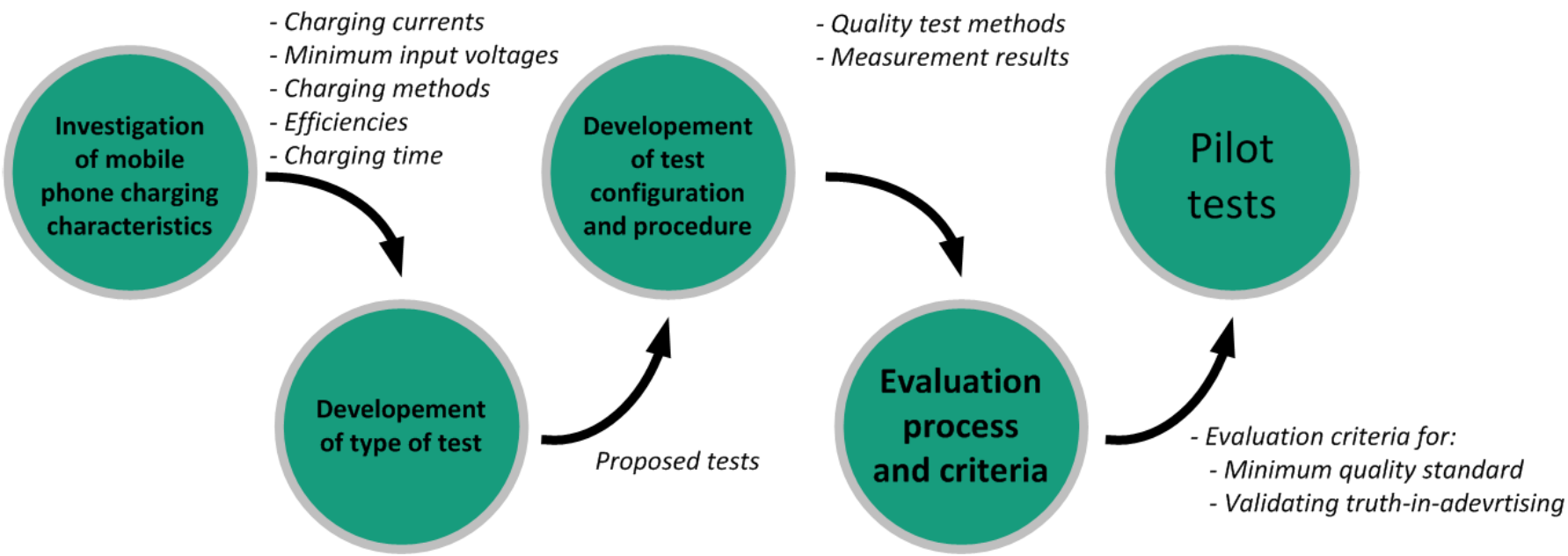
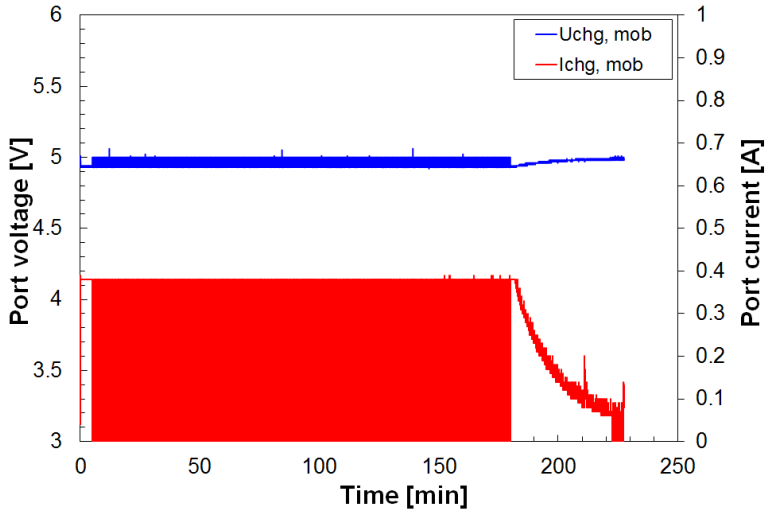
Methodology



Investigation results

Basic mobile phone charging characteristics

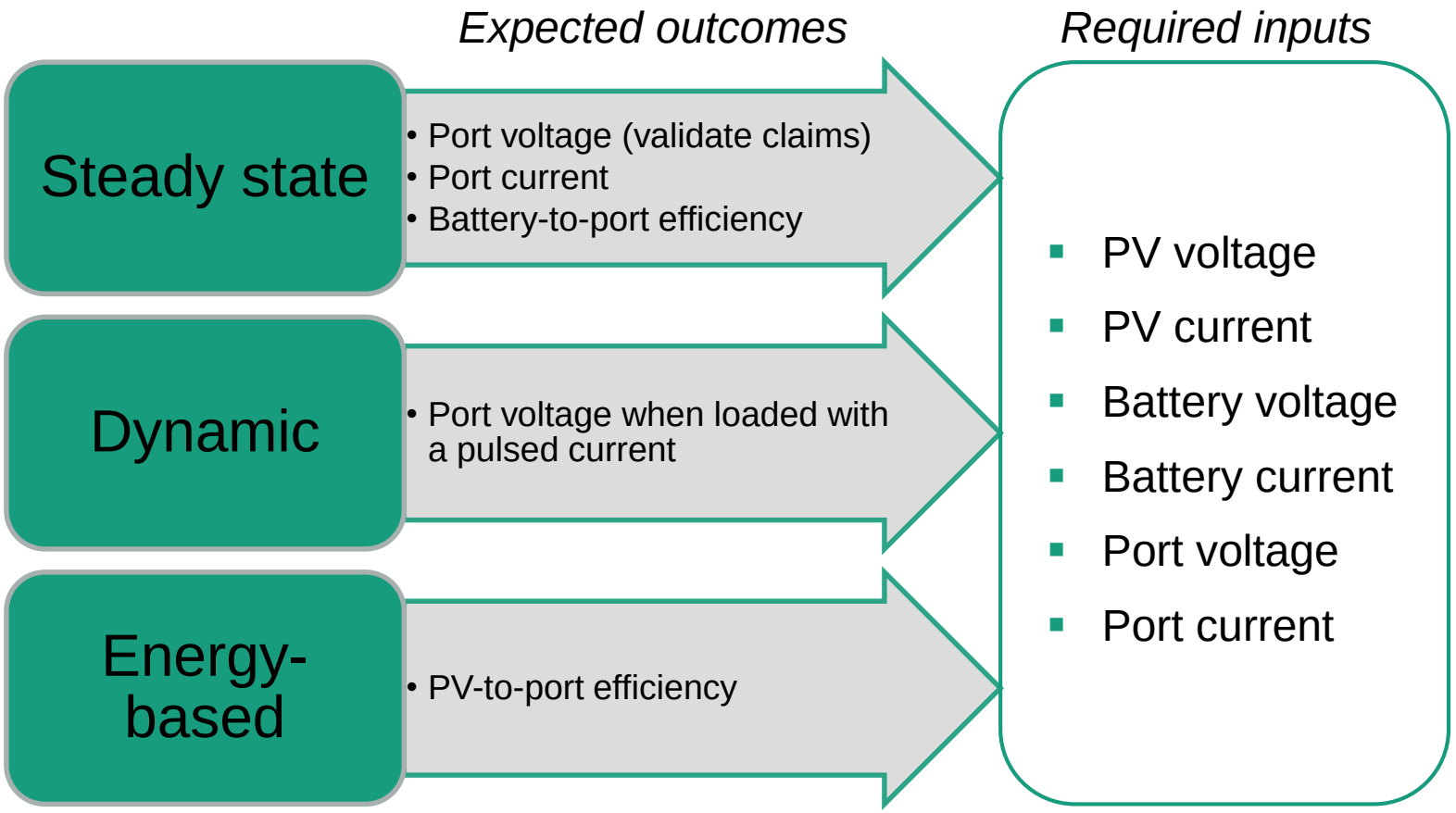
- Results summary from four tested mobile phones
  - Charging methods: Pulse and switching-mode
  - Charging current: < 1 A
  - Internal charger efficiency: 60% to 90%, $\bar{\eta}$= 76%
  - Minimum input voltage: 4.57 V



Pulse charging behavior of the measured basic mobile phone

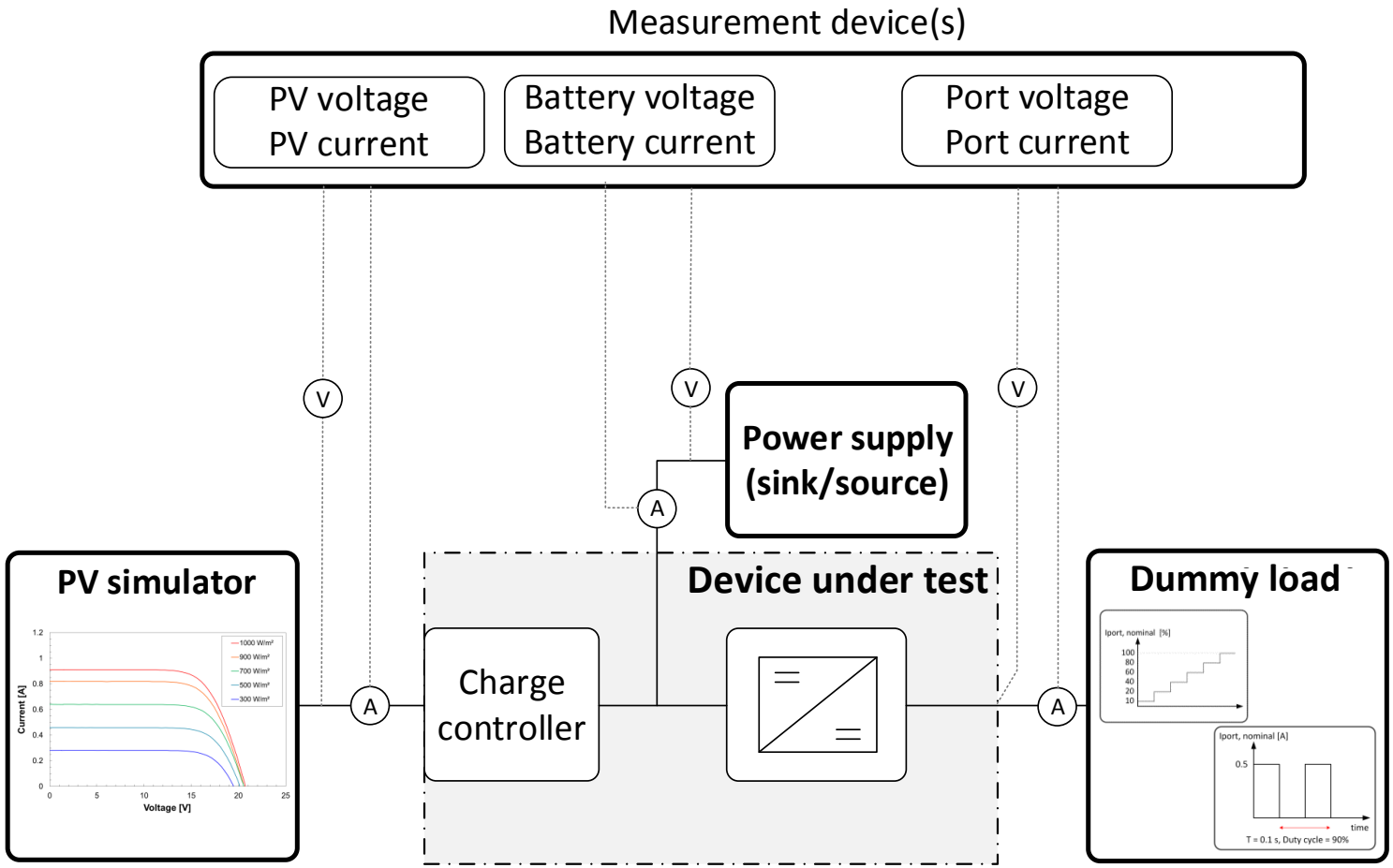
Development of test framework

Expected outcomes and required inputs matrix for test configuration



Development of test framework

Test configuration and procedures of steady state test

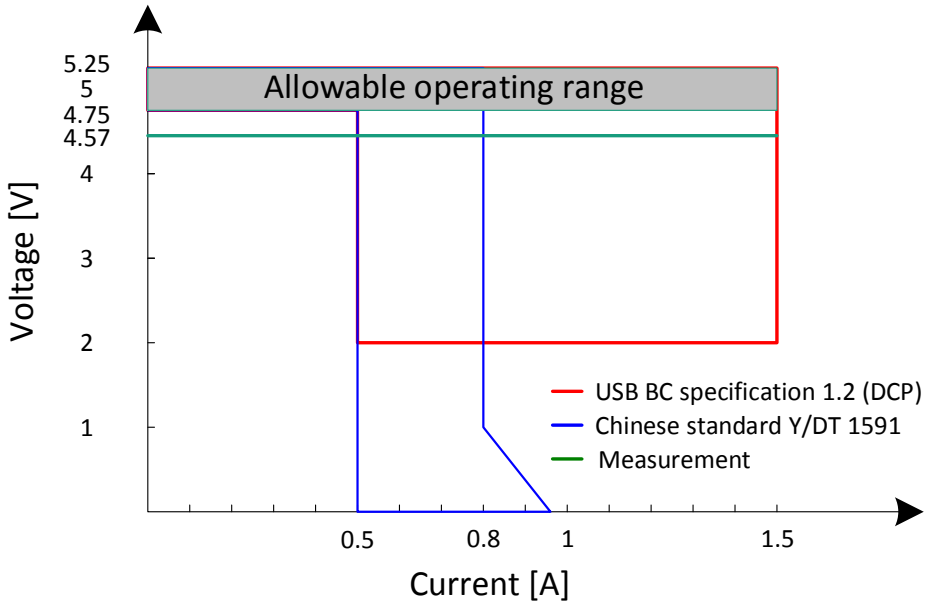


Test configuration

Development of test framework

Evaluation process and criteria

- Evaluation of steady state test
  - Port voltage at different battery voltage and load current:
    - Minimum quality standards (Q) → 4.75 V ≤ U_{port} ≤ 5.25 at 0.5 A
    - Truth-in-advertising (TIA)
  - Battery-to-port efficiency calculation



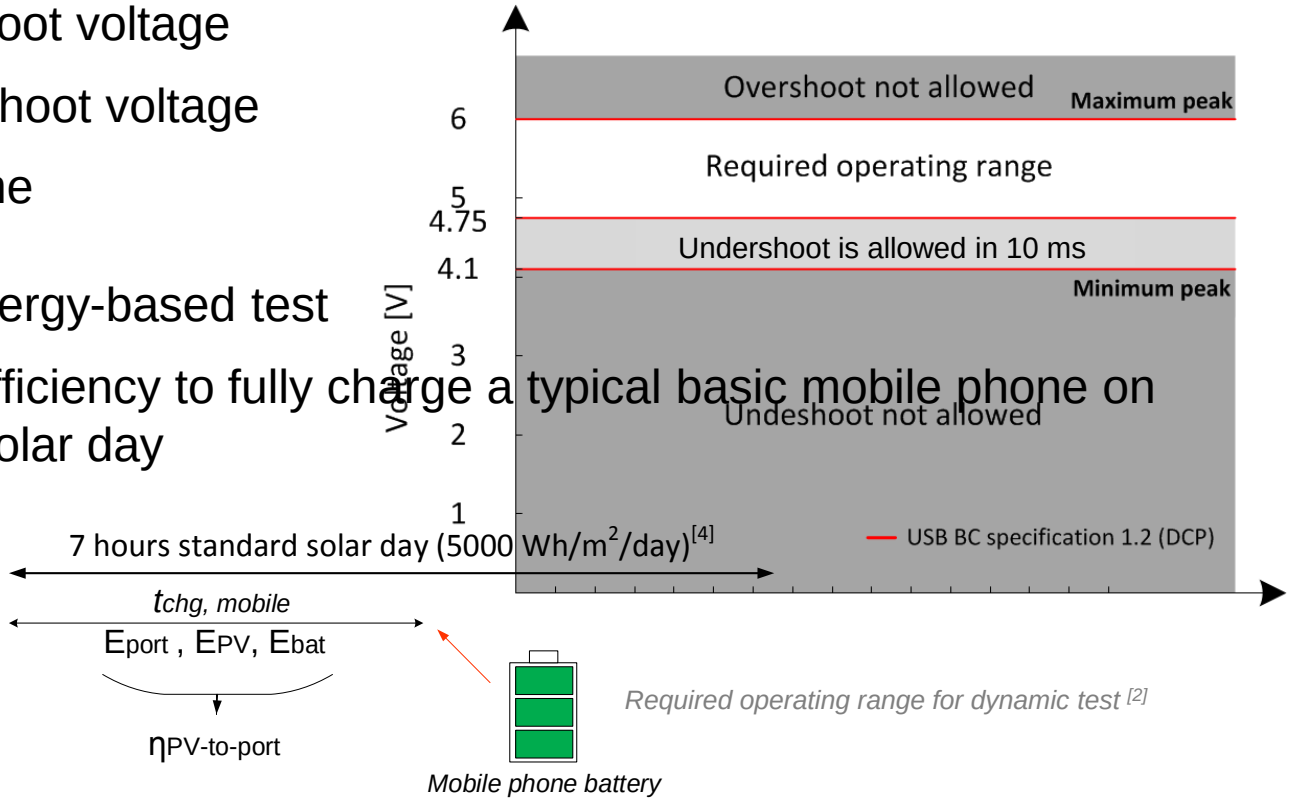
Required operating range for steady state test [2,3]

Source : [5]USB Implementers Forum, 2012., [8]Ministry of information industry of People's Republic of China, 2009.

Development of test framework

Evaluation process and criteria

- Evaluation of dynamic test
  - Peak overshoot voltage
  - Peak undershoot voltage
  - Transient time
- Evaluation of energy-based test
  - PV-to-port efficiency to fully charge a typical basic mobile phone on a standard solar day



Required operating range for dynamic test [2]

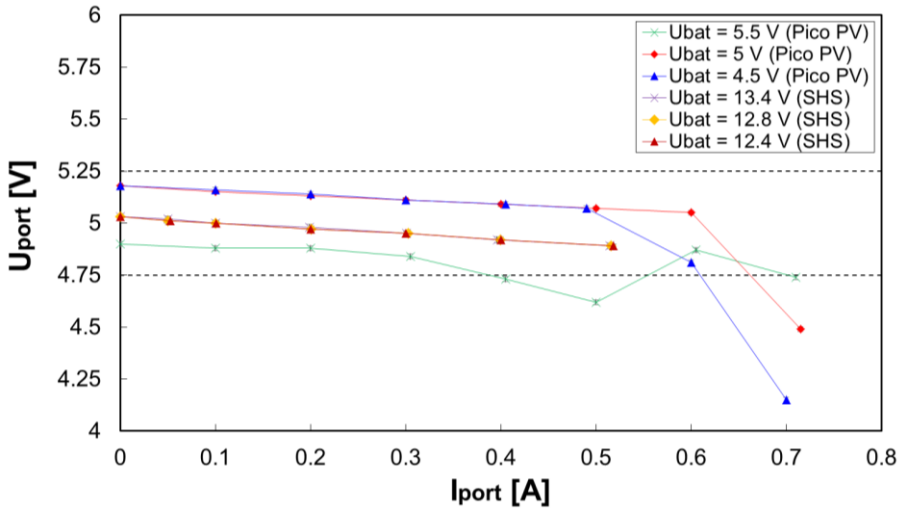
Illustration of PV-to-port efficiency calculation

Source : [2]USB Implementers Forum, 2012., [4]IEC 62257-9-5, 2013.

Pilot tests results

Steady state test – Port voltage assessment

- Results summary
  - $U_{port} = f(U_{battery}, I_{load})$
  - Pico PV has difficulty to regulate the output voltage which leads to a fail result

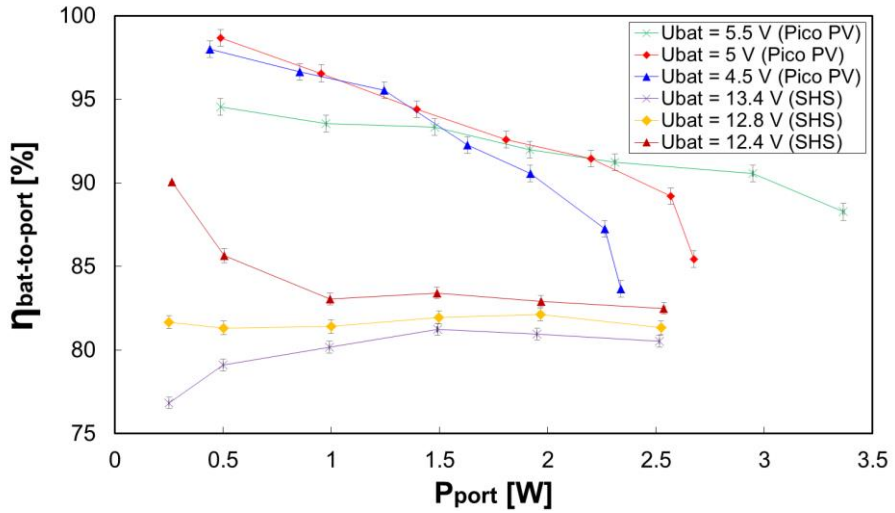


Port voltage of typical Pico PV and Solar home system at different battery voltages and load currents.

Pilot tests results

Steady state test – Battery-to-port efficiency

- Results summary
  - $\eta = f(U_{battery}, I_{load})$
  - Weighted averaged will be used for energy service calculation

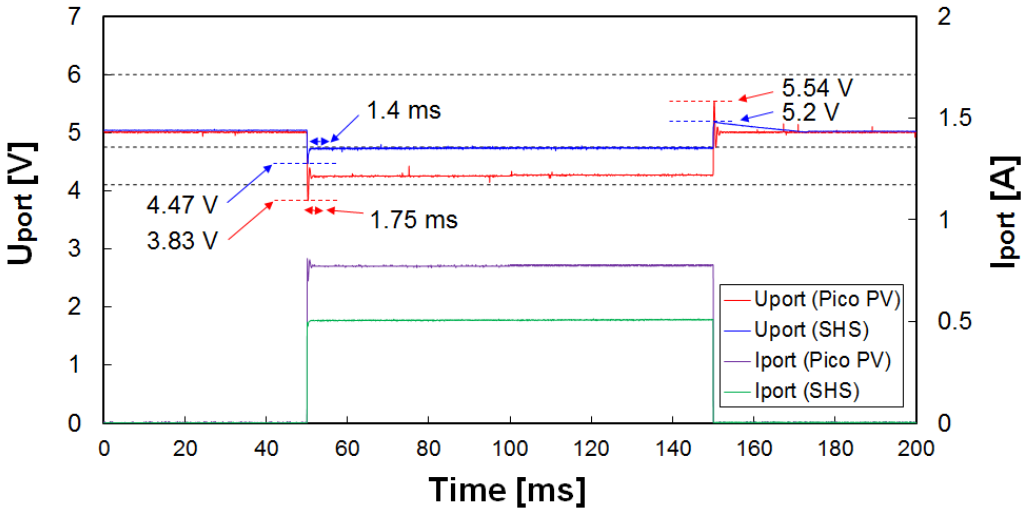


Port voltage of typical Pico PV and Solar home system at different battery voltages and load currents.

Pilot tests results

Dynamic test

- Results summary
  - The load should be switched as fast as possible
  - Switching noises should be mitigated prior the evaluation to exclude the high frequency component

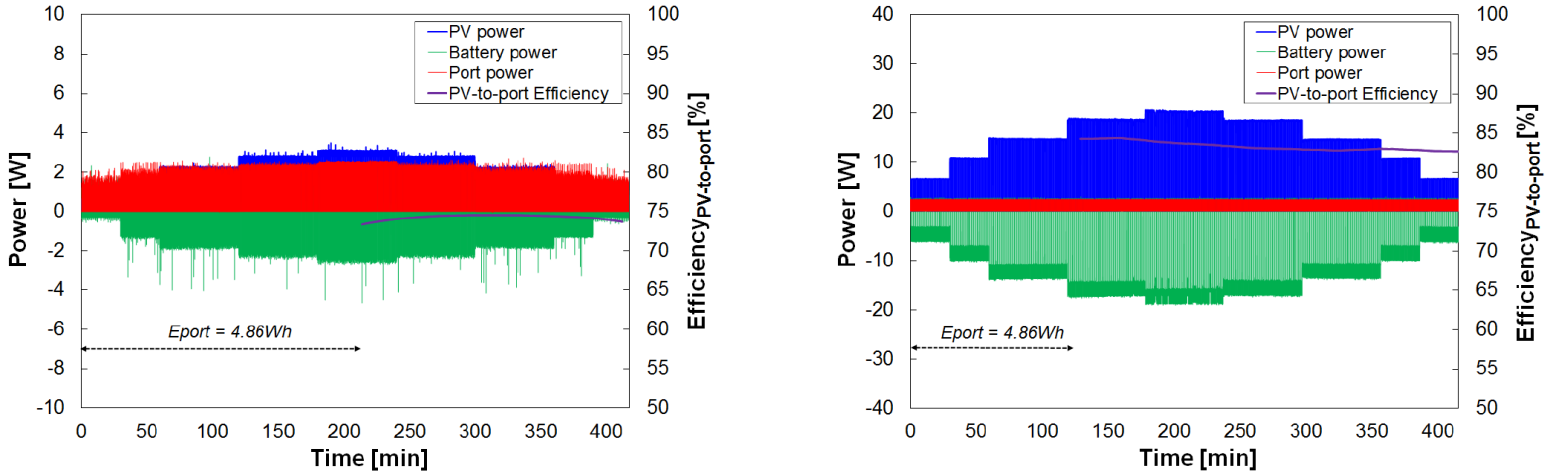


Transient voltages of at the port when the pulse is triggered.

Pilot tests results

Energy-based test

- Results summary
  - Pico PV system took a longer period to fully charge a mobile phone (leads to a longer period of mesurement)
  - The PV-to-port efficiency is relatively constant regardless the amount of irradiance



Energy-based test results of Pico PV (left) and solar home system (right)

Conclusion

- Steady state, dynamic, and energy-based tests are sufficient and reliable to assure the quality and truth-in-advertising of the USB charging ports:
  - The steady state and dynamic tests are important to ensure that a mobile phone will be succesfully and safely charged based on the permitted operating voltage
  - The energy-based test allows to evaluate the capability of a product to charge a mobile phone in terms of power and energy
  - The battery-to-port and PV-to-port efficiencies are also obtained to calculate the daily energy service of the product for charging mobile phones
- The test procedure should be tested on more products with different sizes and technologies

Thank you for your attention!

Now is your turn!

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References

[1] C. Simpson. Load Transient Testing Simplified. Application Note 1733. Texas Instruments. (November), 2007.

[2] USB Implementers Forum. Battery Charging Specification (Including errata and ECNs through March 15, 2012), 2012.

[3] Ministry of Information Industry of People's Republic of China. Technical Requirements and Test Method of Charger and Interface for Mobile Telecommunication Terminal Equipment. YD/T 1591, 2009

[4] IEC Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-5: Integrated system - Selection of stand-alone lighitng kits for rural electrification. IEC 62257-9-5, 2013.